Enabling All-Access Mobility for Planetary Exploration Vehicles via Transformative Reconfiguration

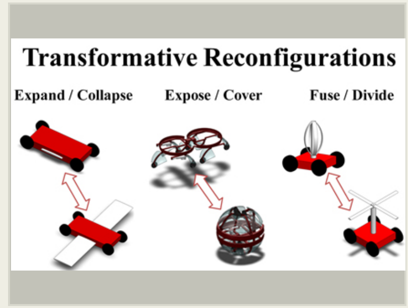
Completed Technology Project (2011 - 2012)

Project Introduction

Investigation of real-time repeatable, reversible changes in physical configuration will yield solutions capable of significant changes to system form. Outcomes from this work will include identifying technologies that facilitate reconfigurability, assessing their strengths and limitations, and developing proof-of-concept prototypes. Similar to the concept seen in recent 'Transformers' movies, this work explores how reconfigurability can enable mobility across diverse, uncertain terrains. Beyond sensing and controls challenges, there has been little work done exploring the application of transformative reconfigurations that deviate from traditional wheeled-rover design. Investigation of real-time repeatable, reversible changes in physical configuration will yield solutions capable of significant changes to system form. Outcomes from this work will include identifying technologies that facilitate reconfigurability, assessing their strengths and limitations, and developing proof-of-concept prototypes. (This is a project within the NASA Innovative Advanced, NIAC, program.)

Anticipated Benefits

The significant uncertainties about terrain conditions make it highly desirable for spacecraft to have robust mobility capabilities. Advancements in system architecture that are gained from the incorporation of reconfigurability will transform our perceptions on the constraints that dictate the terrain on which these systems can perform and the range they are capable of achieving. Further, the evolution of this system architecture over the course of multiple missions can lead to increased cost savings and the ability to rapidly explore new, harsh environments



Project Image Enabling All-Access Mobility for Planetary Exploration Vehicles via Transformative Reconfiguration

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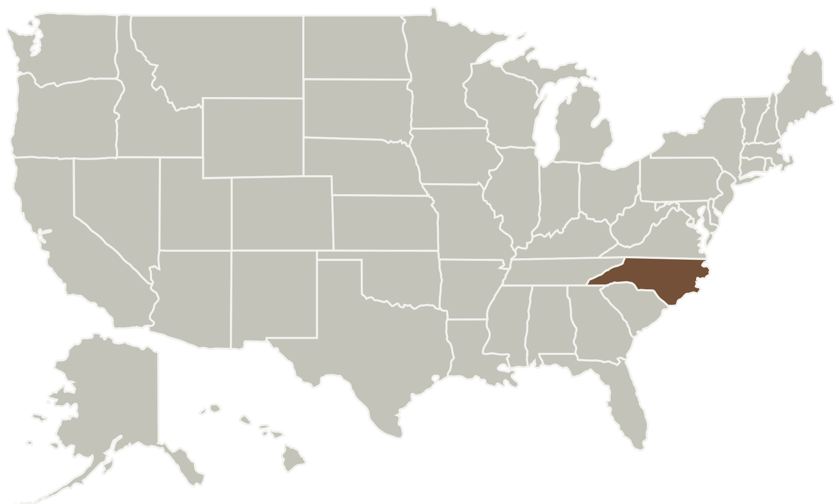
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
North Carolina State University at Raleigh	Lead Organization	Academia	Raleigh, North Carolina

Primary U.S. Work Locations
North Carolina

Project Transitions

September 2011: Project Start

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

North Carolina State University at Raleigh

Responsible Program:

NASA Innovative Advanced Concepts

Project Management

Program Director:

Jason E Derleth

Program Manager:

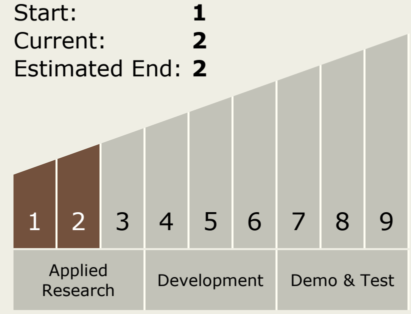
Eric A Eberly

Principal Investigator:

Scott Ferguson

Technology Maturity (TRL)

Start: **1**
Current: **2**
Estimated End: **2**



September 2012: Closed out

Closeout Summary: Effective large-scale exploration of planetary surfaces req uires robotic vehicles capable of mobility across chaotic terrain. To date, rovers sent to Mars have been based on the standard rocker-bogie style architecture, a nd hence have been limited to exploring relatively flat, even terrain. In search of game-changing technologies that can enable robotic exploration of much more c hallenging terrains, we have examined the role that transformation principles ca n play in facilitating the development of such technologies. As part of this effort we made use of three senior design teams to generate new ideas, and also empl oyed three graduate students who worked in this area as part of their thesis and class work. The basic strategy we employed was to: -generate configuration cha nges using transformation principles (e.g. using brainstorming); -identify promis ing concepts that use transformation to explore different types of terrain; -creat e virtual and physical prototypes; -develop analytical models describing system motion and function over randomly generated random terrain profiles; -and, con duct a quantitative evaluation of system performance. After analyzing 31 concep ts, a pattern emerged; namely that the most fruitful transformation principles fo r planetary rover exploration are expand / collapse and expose / cover. Fuse / di vide was also found to be useful, but this is not new, as NASA has been using th is principle for over 40 years. Additionally, while reorientation can enable game-changing architecture changes when combined with other transformation princip les, it does so from a secondary support role. In addition to identifying the most promising transformation principles, we also chose to develop three system arch itectures: a glider/base system for exploring Mars' Melas Chasma, an Air Canno n system for exploring Mars' Valles Marineris, and a transforming Roving-Rolling Explorer (TRREx) for exploring Mars' Hellas Basin. While this development mostl y occurs to validate initial concept feasibility, we also present a strategy for asse ssing the system-level effectiveness of architecture transformations in the prese nce of chaotic terrain. A hi-fidelity simulation environment is used to quickly run a myriad of test scenarios on the TRREx concept and the traditional rocker-bogie architecture. Four rovers - two architectures using two size scales - are tested a cross various levels of ground traction, slope, and rock field density. Utility theor y is combined with identified performance measures to explore rational architect ure selection across potential missions generated as a combination of terrain ch allenges. From this study, we conclude that architecture decisions for a given mi ssion must be based on mission profile, terrain encountered, and the size of the rover to be deployed. In summary, we have used this Phase I effort to engage i n a very broad exploration of concepts enabled by system transformation, identi fied the concepts of expand/collapse and expose/cover as being particularly pro mising with respect to developing game changing architectures for planetary ex ploration, have performed detailed development and analysis of three particularl y promising technologies, and have developed techniques for evaluating the perf ormance of these new concepts with respect to how well they can achieve desire d exploration goals over rough and chaotic terrains. While this study has explore d the design space enabled by transformation principles, future efforts must cha racterize and explore the tradespace for specific architectures. Fundamentally, t his requires the aggregation of information from the engineering and mission sci ence disciplines. This will require appropriate measures of risk, complexity, and performance to be explored within existing decision-making frameworks develop ed by the engineering design community. Additional efforts must be undertaken to identify the key technologies that need to be created, improved, or adopted if the proposed architectures are to be further matured.

Technology Areas

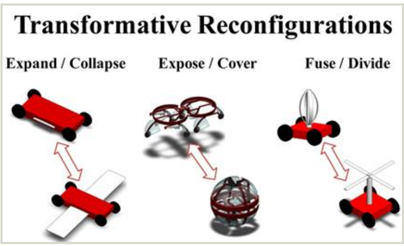
Primary:

- TX15 Flight Vehicle Systems
  - └ TX15.1 Aerosciences
    - └ TX15.1.6 Advanced Atmospheric Flight Vehicles

Target Destinations

The Moon, Mars, Others Inside the Solar System

Images



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(https://techport.nasa.gov/image/102079)